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3D X-Ray Computed Tomography (XCT) of Fatigue Damage Evolution in UD Glass Fibre Composite

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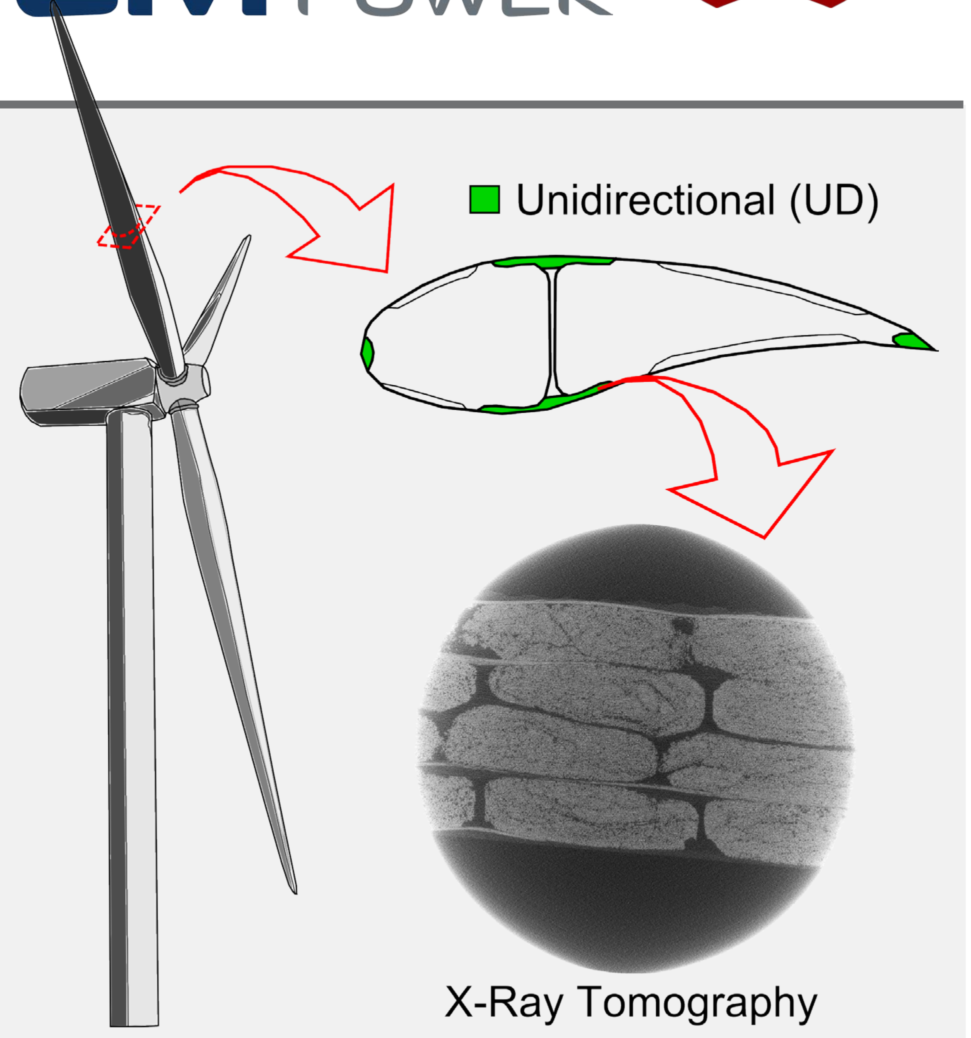
Unidirectional (UD) glass fibre composites are used for wind turbine blades due to their high stiffness to weight ratio. One of the main limiting factors of increasing the blade length is the lack of knowledge on fatigue damage evolution, making it necessary to include high safety factors. This study considers gaining knowledge on fatigue behaviour through experiments for later use in simulations.



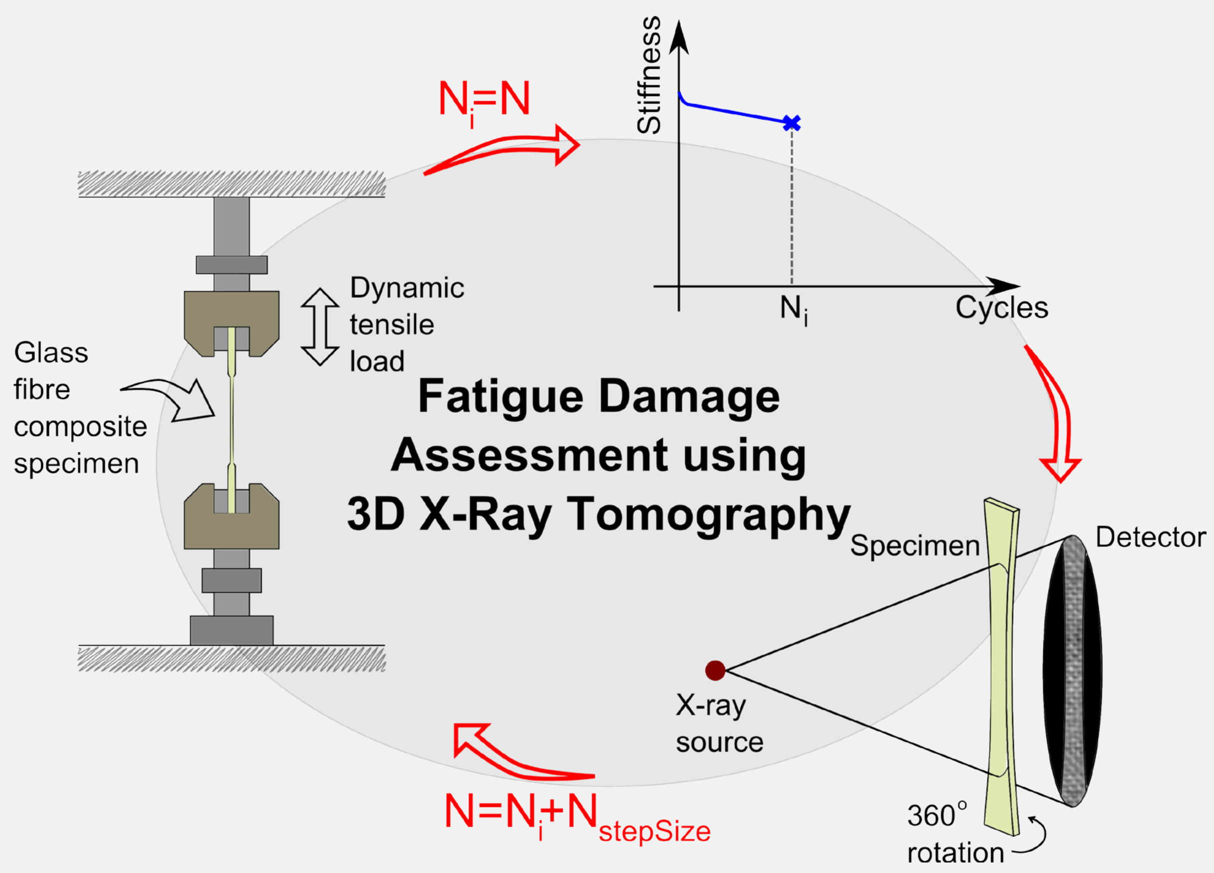
UD glass fibre composite material is used for the load carrying parts of the wind turbine blade considered (marked with green). The glass fibres are gathered in bundles which are held in place by stitching them to a backing layer. The glass fibres are around 16 microns in diameter and are surrounded by a polyester resin.

Overall Experimental Approach

Tension fatigue testing is to be coupled with XCT to obtain a method of linking microstructural material parameters with the fatigue damage evolution.

By scanning the glass fibre composite fatigue test specimen at several points during a tension fatigue test, information on the relationship between the microstructure and damage evolution can be extracted.

The first challenge related to this is to obtain a sufficient resolution for identifying cracked fibres.



The specimen is subjected to a number of load cycles leading to a stiffness drop. The sample is scanned for quantification of damage. The same sample is then subjected to an additional number of cycles, and this loop is repeated until fracture.

XCT Damage Quantification

The fatigue damage and material microstructure is to be identified from the 3D reconstruction of the scan.

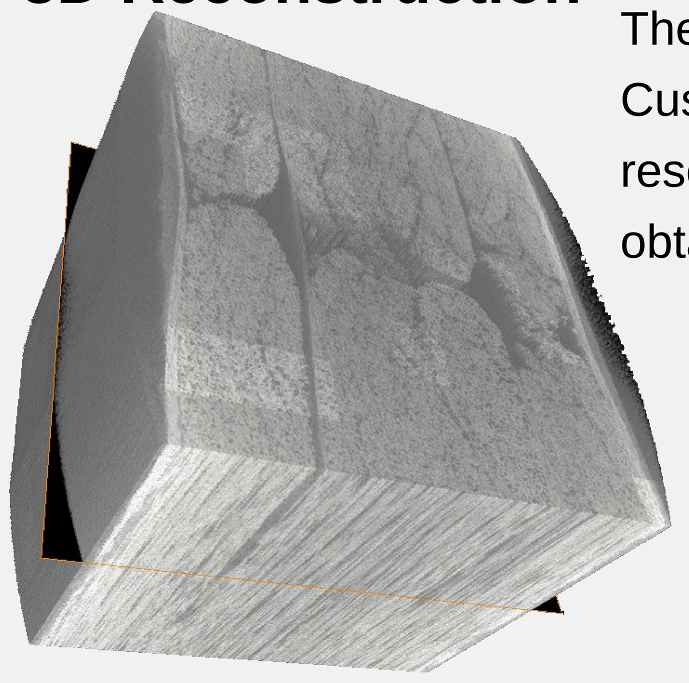
Parameters to be quantified related to material characterization could be:

- Fibre radius and variation
- Fibre misalignment along length
- Number of contact points between fibres

Parameters to be quantified related to the assessment of damage could be:

- Number of fibre cracks
- Number of matrix cracks in backing layer

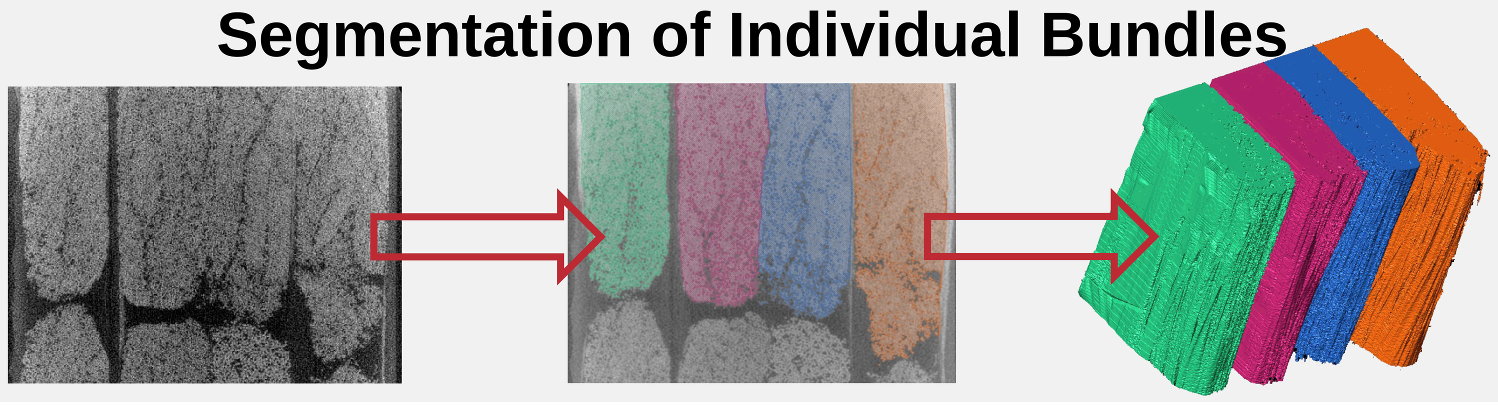
3D Reconstruction



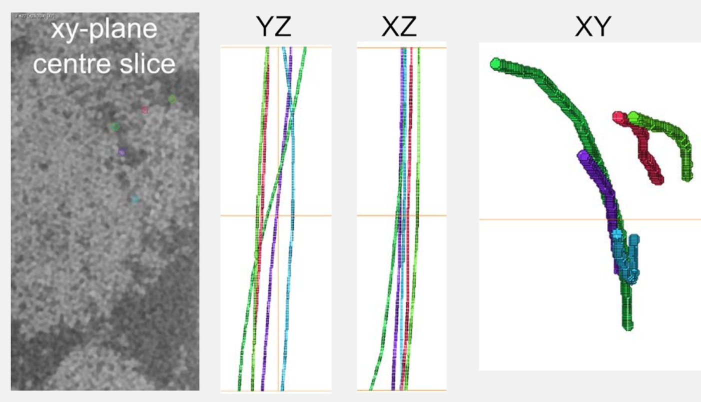
Initial 3D XCT Experiment

The initial experiment was performed with the goal of determining what can be seen when using a Nicon Custom Bay (225/320 kV) scanner. This equipment can scan large specimens but with a maximum resolution of 3 microns (voxel size). A full size fatigue specimen was scanned with a small field of view to obtain the best resolution. Segmentation and visualization was done using the commercial software Avizo.

Segmentation of Individual Bundles



Following Individual Fibres



Avizo was used to follow some fibres along the length, however this was done manually. The fibres were difficult to distinguish from each other with the resolution obtained.

Conclusions

- Possible to segment bundles at this resolution with Avizo, however some manual work is necessary – especially when the bundles are in contact.
- Possible to visually follow the position of most of the fibres at this resolution, however it becomes difficult when fibres are close to each other.
- **Not possible to see any cracks with this setup!**
- **Not possible to determine fibre radii with this setup!**

Next Steps

- Apply tension to specimen while scanning in order to open cracks making them easier to visualize
- Perform the scan on a different scanner (e.g. Zeiss X-Radia Versa) where it is possible to obtain a higher resolution.
- Develop segmentation tools for automatically performing material and damage parameter quantification.

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